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## Research & Development Center

Report No. CG-D-03-17

# Preliminary Marine Safety Risk Assessment, Brandon Road Lock & Dam Invasive Species Control Measures

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December 2016



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Mr. Jim Fletcher  
E&W Branch Chief  
United States Coast Guard  
Research & Development Center  
1 Chelsea Street  
New London, CT 06320



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## **EXECUTIVE SUMMARY**

The Coast Guard Research and Development Center (RDC) performed this preliminary risk assessment at the request of the Ninth Coast Guard District. This effort, funded by the Environmental Protection Agency (EPA) under the Great Lakes Restoration Initiative, addresses possible effects on marine safety and navigation safety due to proposed invasive species control measures located in the vicinity of the Brandon Road Lock and Dam (BRLD) Navigation Project on the Des Plaines River near Joliet, IL. This preliminary risk assessment provides the Coast Guard operational commander evaluative input for the U. S. Army Corps of Engineers (USACE) Tentatively Selected Plan (TSP) submittal.

As the USACE project team is conducting full-scale environmental and economic analyses associated with the control measures, this work focuses strictly on the navigation- and marine-safety related risks that might directly affect waterway users and the general public.

This preliminary marine safety risk assessment takes into consideration commercial and recreational vessel operations and activities, including recreational activities alongside or on structures and landscape adjacent to the Des Plaines River, and how a range of invasive species control measures, now under consideration, might affect the safety of waterway activities in these areas. This work includes discussion of possible control measures and general consequence categories associated with those mitigation measures, development of risk relationships associated with vessel-traffic and vessel operations near control-measure locations, and broad-scope, marine-safety and navigation-safety risk-mitigation strategies.

With the inherent uncertainties as to actual effects of proposed invasive species control measures, implementation of actual marine-safety risk-mitigation strategies must wait until structures and apparatus are in place and tested. This preliminary analysis indicates that, for the most part, the Coast Guard, in conjunction with the Corps of Engineers, the Illinois Department of Natural Resources, and commercial and recreational waterway interests can combine navigation safety regulations, best practices, and operational interventions associated with the control measures in a suite of strategies to minimize risk for the affected area.

As this is a preliminary risk assessment, Coast Guard operational commanders should further assess the information presented here, and new information when developed, as control-measure planning advances to design development, modeling and testing. Once individual control measures begin operational testing, additional risk assessment efforts may be in order, including a formal risk assessment that accounts for all control measures, once the measures are ready for service.



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## **LIST OF ACRONYMS, ABBREVIATIONS, AND SYMBOLS**

AIS	Aquatic Invasive Species
BRLD	Brandon Road Lock and Dam
CSSC	Chicago Sanitary and Ship Canal
EPA	Environmental Protection Agency
LDB	Left Descending Bank
LOA	Length over-all
MM	Mile Marker
PIW	Person in the Water
RDB	Right Descending Bank
RDC	Research and Development Center
RNA	Regulated Navigation Area
TSP	Tentatively Selected Plan
USACE	United States Army Corps of Engineers
USCG	United States Coast Guard
USGS	United States Geological Survey



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## **1 INTRODUCTION**

The Coast Guard Research and Development Center (RDC) performed this preliminary risk assessment at the request of the Ninth Coast Guard District. This effort, funded by the Environmental Protection Agency (EPA) under the Great Lakes Restoration Initiative, addresses possible effects on marine safety and navigation safety due to proposed invasive species control measures located in the vicinity of the Brandon Road Lock and Dam (BRLD) Navigation Project on the Des Plaines River, near Joliet, IL. This preliminary risk assessment provides the Coast Guard operational commander evaluative input for the U. S. Army Corps of Engineers (USACE) Tentatively Selected Plan (TSP) submittal.

A navigation safety risk assessment, regardless of type, typically applies to project proposals where USACE serves as the permitting agency reviewing a request to issue a “Section 10” permit. This is not the case for the BRLD Aquatic Invasive Species (AIS) control measures. In this instance, USACE is the organization responsible for the “proposal.”

This “preliminary risk assessment” is a hybrid of the procedures and assessments described in Coast Guard Training, Tactics and Procedures 3-71.7. As the USACE project team is conducting full-scale environmental and economic analyses associated with the control measures, this work focuses strictly on the navigation- and marine-safety related risks that might directly affect waterway users and the general public. (“Risk” is equal to the probability or likelihood of an event occurring multiplied by the consequence or “cost” associated with that event.)

In general, a marine safety risk assessment identifies individual events or combinations of events that might occur in a particular area, estimates the probability of individual events or combinations of events occurring (often resulting in an event tree), determines consequence values for each event or combination of events, and as a final target, uses the determined risk values to address a range of mitigation factors. In understanding the benefit of a risk assessment, analysts often relate the cost of mitigation measures to the cost associated with the consequence.

This preliminary marine safety risk assessment takes into consideration commercial and recreational vessel operations and activities. This includes recreational activities alongside or on structures and landscape adjacent to the Des Plaines River, and how a range of invasive species control measures, now under consideration, might affect the safety of waterway activities or those activities that occur in these areas.

With the inherent uncertainties related to the effects of proposed invasive species control measures, implementation of actual marine-safety risk-mitigation strategies must wait until structures and apparatus are in place and tested. No model exists today (December 2016) that combines the different invasive species control measures into a detailed operational scenario. Many of the control-measure plans are in the early, concept-development phase.

Navigation-safety and marine-safety risk reduction planning must accompany control-measure design, construction, implementation and operation. Decision makers must include control-measure monitoring and emergency “interventions” to insure safety. The Coast Guard operational commanders need to determine and plan for a level of emergency response for the electric barrier operation. Operational commanders should undertake further risk assessment work for the individual control-measures as implemented, and



follow up with a formal risk assessment of the combined systems once USACE completes all construction and testing.

This preliminary analysis indicates that, for the most part, the Coast Guard, in conjunction with the Corps of Engineers, the Illinois Department of Natural Resources, and commercial and recreational waterway interests can combine navigation safety regulations, best practices, and operational interventions associated with the control measures in a suite of strategies to minimize risk for the affected area.

## **2 BACKGROUND**

As a preliminary risk assessment, this work includes discussion of the following:

- a) Possible control measures and broad consequence categories associated with those mitigation measures,
- b) development of risk relationships associated with vessel-traffic and vessel operations near anticipated control-measure locations and non vessel-related activities that occur in the vicinity of the downstream approach to BRLD, especially fishing or hunting from shore, and other types of activities,
- c) and broad-scope marine-safety and navigation safety risk mitigation strategies.

Previous Coast Guard Research and Development Center (RDC) Illinois Waterway research included a study on the ability to conduct rescue in electrified water (Slater, et al., 2011) and a quantitative marine safety risk assessment for the Chicago Sanitary and Ship Canal (CSSC) in vicinity of the Romeoville, IL electric barriers (Lewandowski, et al., 2013). Through these previous efforts, RDC gained a working knowledge of a portion of the Illinois Waterway, its commercial and recreational activity, and a general appreciation for the interactions between aquatic invasive species (AIS) control measures and an active waterway. The CSSC risk assessment provided the Coast Guard operational commander actual values for potential losses-per-year, and recommendations to limit those losses while continuing safe vessel operations. The report also provided a basis to adjust and apply regulated navigation area and safety zone rules.

The CSSC study investigated the following general *consequence types*.

- Commercial or Recreational Activity-Related Electric Shock.
- Contact-Related Electric Shock.
- Person in the Water (PIW)-Related Electric Shock.
- PIW Rescuer-Related Electric Shock.
- Spark-Related Vapor Ignition.
- Congestion-Related Collision, Allision, or Sinking (CAS).

Though these consequence types still have applicability to the BRLD electric barrier project, other marine safety risk events and consequence types require identification, categorization, and possible analysis. Also, we cannot apply the same, exact techniques used for the CSSC risk analysis to the BRLD project. Prior to the quantitative risk assessment, CSSC had existing operating conditions in place, including an active electric barrier, with knowledge of the extent of the electric field, and physical control measures on the canal banks to prohibit unrestricted access to areas associated with the barrier infrastructure (and to some extent, the canal areas of electrified water) There were also existing, regulatory measures and provisions



(Safety Zone and Regulated Navigation Area) that when followed, reduce the opportunity for “adverse-consequence events.”

With this BRLD effort, we can identify similarities and differences between BRLD & CSSC as applicable, but must also attempt to identify interactions and potential consequences associated with multiple control measures, including those with a significant degree of unknown or uncertainty.

### **3 POSSIBLE BRLD INVASIVE SPECIES CONTROL MEASURES**

This preliminary risk assessment supports the USACE TSP submittal, but it also addresses additional control measures *not specifically in the TSP* that may be under consideration for future incorporation in the full suite of BRLD strategies. Taking this approach provides the CG operational commander a basis for later risk-research requirements before actual control measure implementation.

This preliminary risk assessment includes the following control measures: electric barrier array, complex noise generators, fish-entrainment water jets, lock flushing, and carbon dioxide application.

This risk assessment specifically excludes issues associated with control-measure construction, control measure maintenance, or “emergency” invasive species control and management measures such as piscicide application, electro-fishing, or targeted overfishing.

#### **3.1 Individual Control Measure Description**

Electric Barrier: The electric barrier is expected to be similar to those in the CSSC at Romeoville, where electrodes of a barrier array lie across the channel bottom, connected to power supply cables through the canal walls, or in the case of BRLD, proposed “engineered-channel” walls. The design includes “parasitic” structures on the bottom of the channel, a short distance upstream and downstream of the electrodes, to limit the upstream and downstream dispersal of the electric field. Figure 1 is from the USACE brochure of the CSSC Barrier. This image shows two of the three, four-electrode barrier arrays at CSSC, the BRLD project plans for one array (with four sets of electrodes).





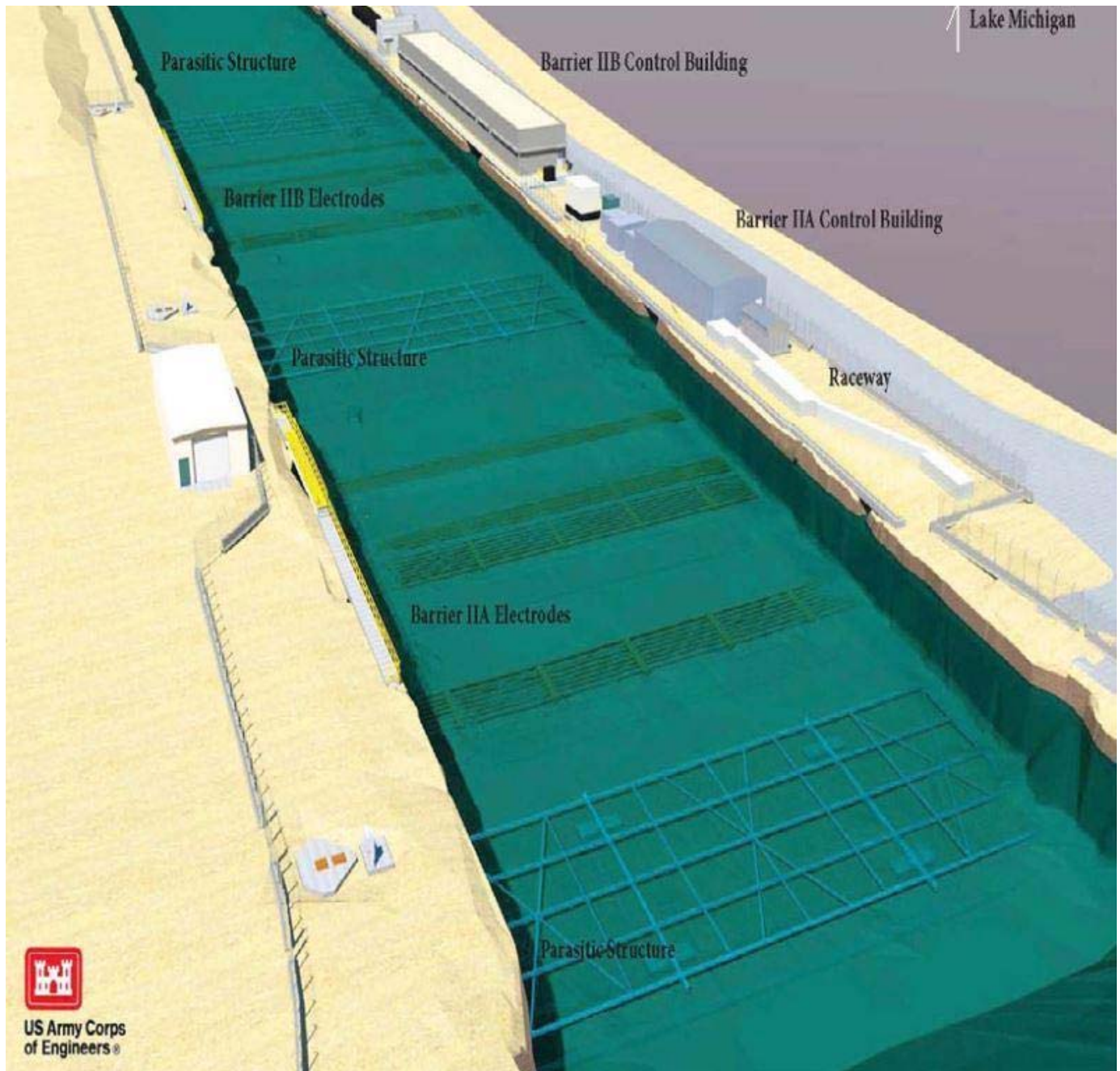


Figure 1. CSSC barrier IIA and IIB components.

USACE and, to a lesser extent, the RDC have conducted extensive research into the operational safety of the electrified barrier system at Romeoville. Figure 2, Figure 3, and Figure 4 are three images from USACE (McInerney, et al., 2011) and RDC testing (Slater, *ibid.*) to give an indication of the hazard zone in the canal with respect to Barriers IIA and IIB. From these images, the “hazardous area” extends approximately 400-450 feet south of a point estimated between the wide and narrow arrays of Barrier IIA, and 400-450 feet north of a point estimated between the wide and narrow arrays of Barrier IIB.

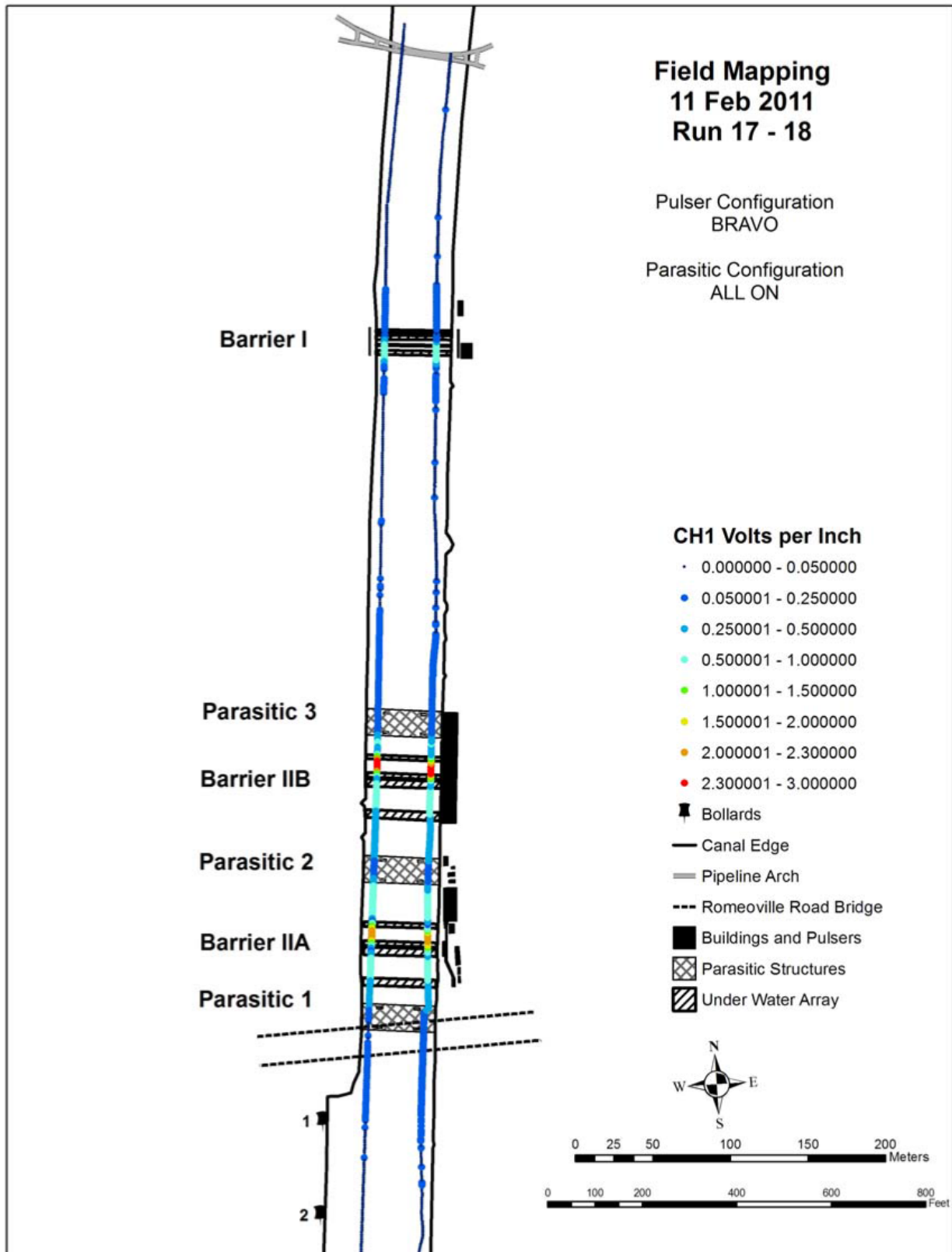


Figure 2. USACE field mapping (McInerney, ibid.)



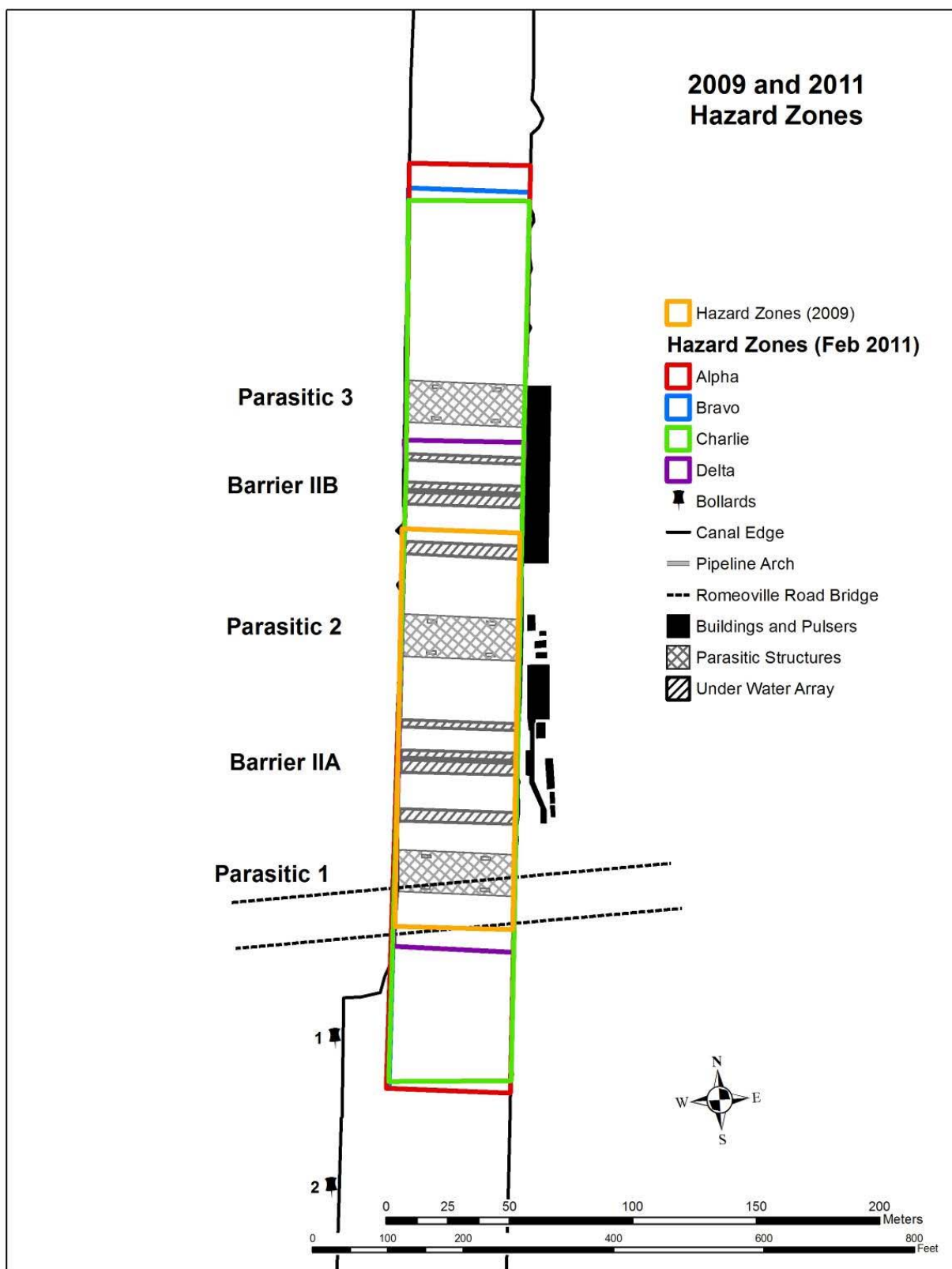


Figure 3. USACE hazard zones (McInerney, ibid.).





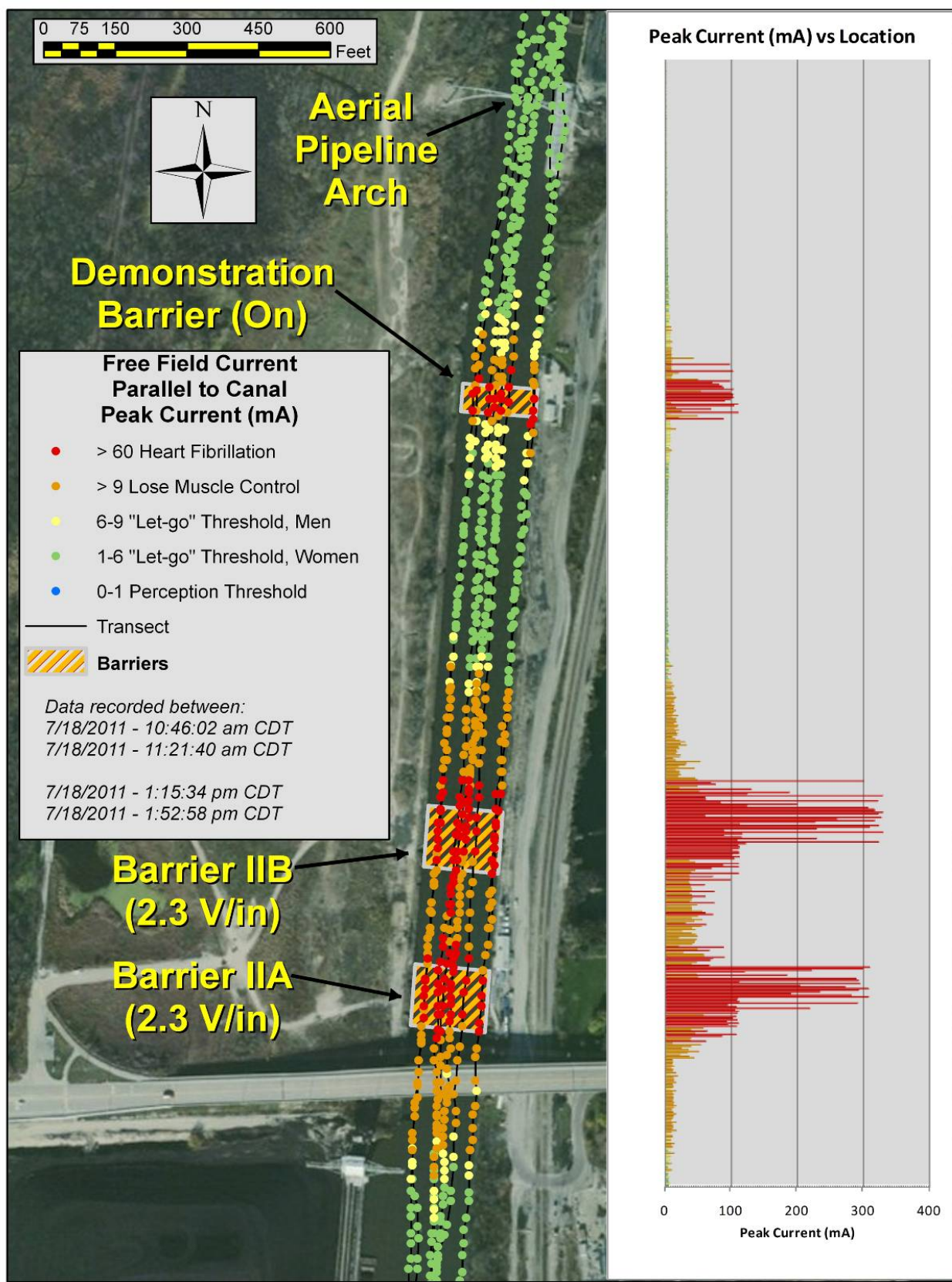


Figure 4. USCG RDC free field current (Slater, ibid.).



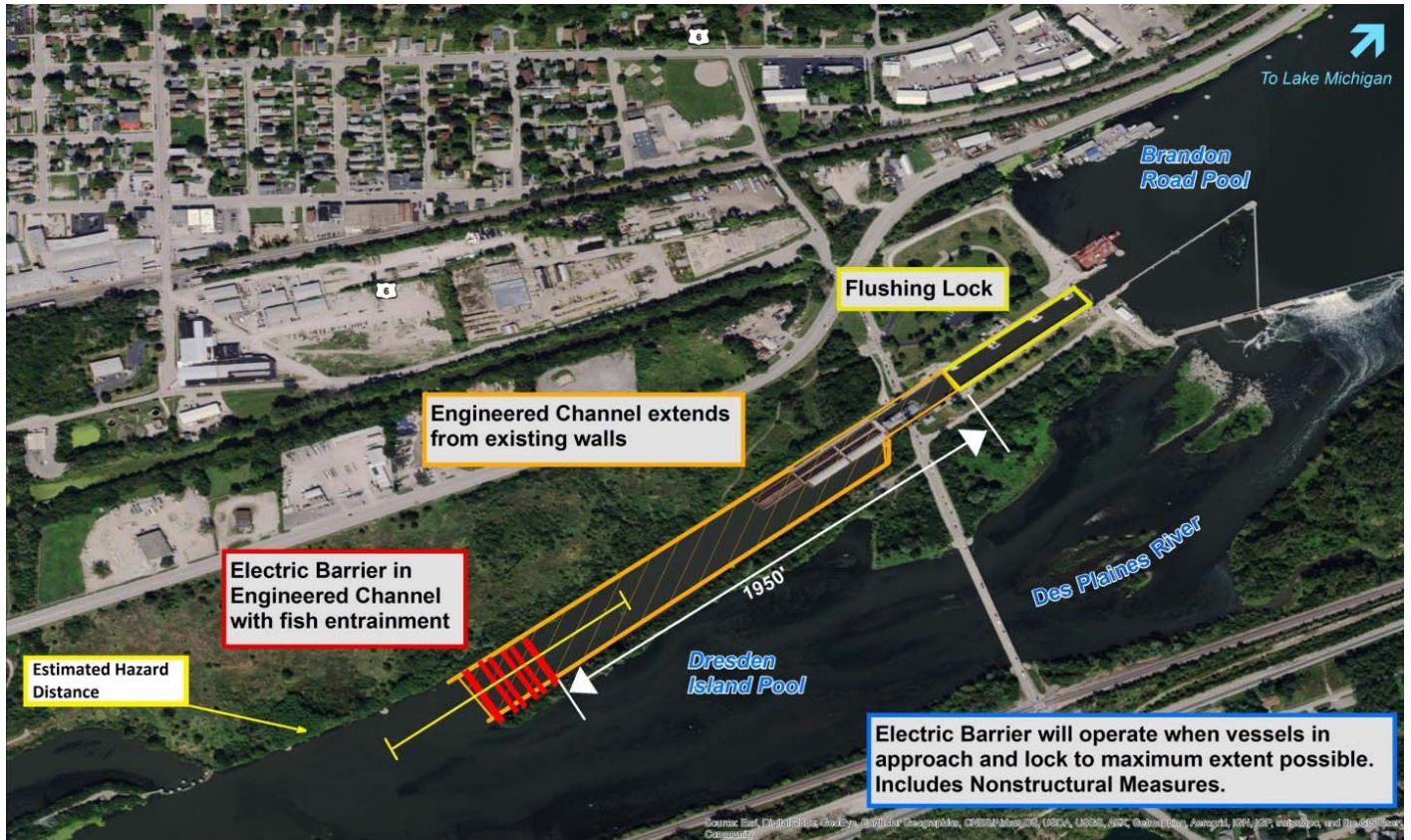


Figure 5. RDC estimate of hazard distance with tentative location of electric barrier.

For the purposes of this risk assessment, we will use an estimated in-water “hazard zone” extending 500 feet, upstream and downstream, from the tentative center of the BRLD barrier location in Figure 5.

**Complex Noise:** This control measure involves transmitting sound through large, underwater transducers (sound generators or “speakers”) into the downstream approach channel. Conceptual planning for testing includes two speakers, one on the lower miter gates and one in the BRD approach channel, on the mooring dolphin just downstream of the left descending bank (LDB) approach wall. See Figure 6, “Locations of complex noise sound generators for Spring 2017 test.”<sup>1</sup> For the Spring 2017 test, the complex noise will be a broadband signal (500-10,000 Hertz) at 180 decibels. As the complex noise strategy has not been tested in this area, USACE has not determined a layout for final siting and installation, should USACE choose this measure. Discussions with navigation interests in August 2016 indicated a potential inclusion of complex noise for both the lock and/or engineered channel (Figure 7)<sup>2</sup>.

<sup>1</sup>Pothoff, J.. “RE: Brandon Road Sound Trial - Overview.” Message to M. Lewandowski. 8 November 2016. Email.

<sup>2</sup>USACE Presentation - GLMRIS-Brandon Road –Navigation Safety Meeting, August 8,2016



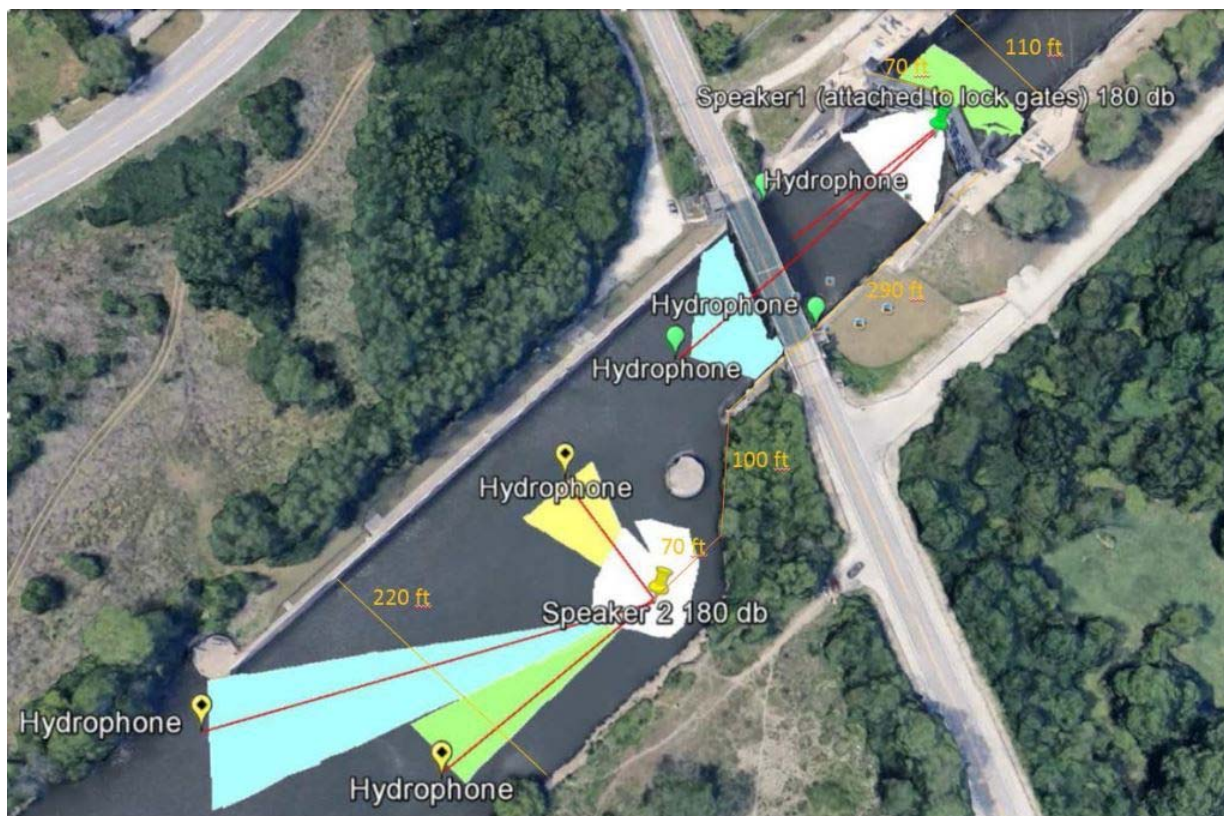


Figure 6. Potential locations of complex noise sound generators for future testing (USACE).



Figure 7. Notional complex noise installation (USACE).

Fish (Barge) Entrainment Mitigation (Water Jets): This measure will have upstream-facing discharge ports on the engineered approach channel bottom to force water at an angle from vertical so as to clear any swimming or floating invasive species out of the box-to-rake- void between two barges (Figure 8).

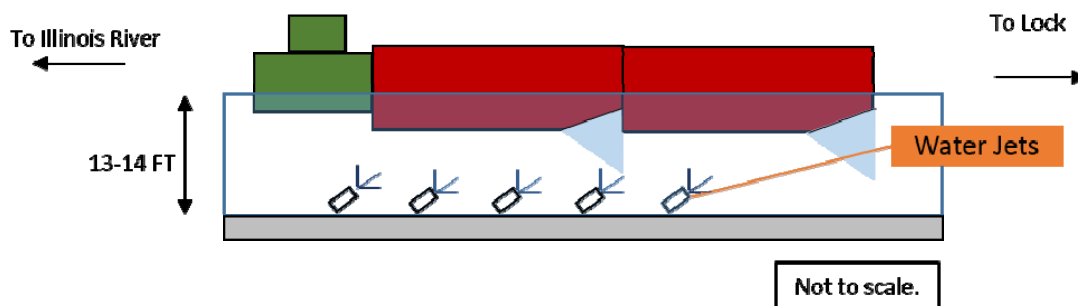


Figure 8. Conceptual profile view of entrainment mitigation control measure (USACE).

USACE anticipates the water-jets will be parallel to the channel, downstream of and within the electric barrier arrays, and possibly immediately upstream of the most upstream array, as well.<sup>3</sup> This places the discharge ports approximately 1850-2100 feet downstream of the lower chamber gates.

Flushing Lock: For this measure, we will assume a potential of re-aligned lock-fill ports that set up a “flushing” flow condition in the lock chamber and approach channel, before lower-gate closure and lock fill. The current operating assumption is flushing the lock when a flotilla stages immediately downstream of the lock. In further investigation of this measure, USACE will likely perform a physical model analysis to assess various operating considerations. One such consideration may be whether a vessel can stage within the lock during lock flushing, in light of safety impacts and flushing effectiveness.<sup>4</sup> The flushing would stop before the closing the lower gates (Figure 9).

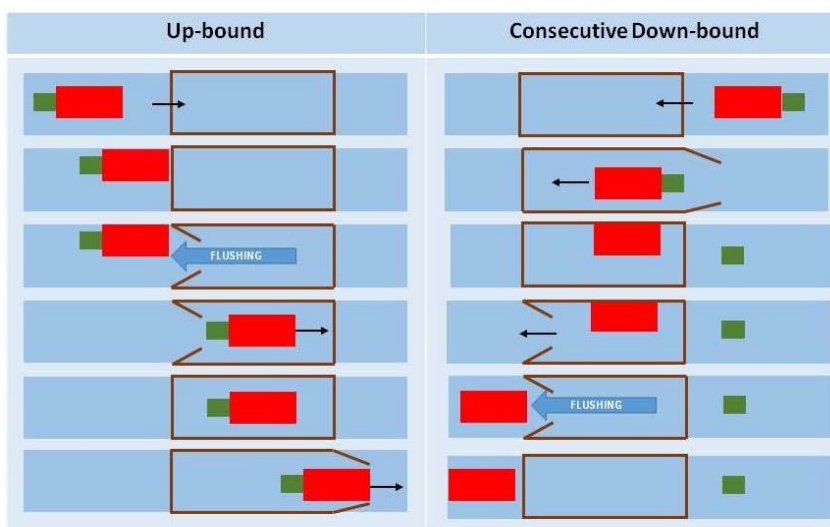


Figure 9. Diagram indicating when flushing occurs during lockage (USACE).

<sup>3</sup> Pothoff, J. “RE: Follow-up on control measure description.” Message to M. Lewandowski. 15 November 2016. Email.

<sup>4</sup> Pothoff, *ibid*.



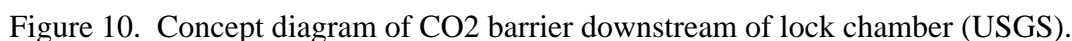


Table 1 is a synopsis of potential primary consequences associated with the five potential control measures. Since the consequences associated with the electrified barrier have been relatively well defined in the CSSC work, and can generally be applied to other electrified barriers, the work here will encompass a qualitative consideration of potential scenarios involving an electrified barrier, the four other control technologies, and possible scenario combinations of the five technologies.



other than the electrified barrier. Also, the consequences defined in Table 1 for the complex noise, water jet, lock flushing, and CO<sub>2</sub> are not, in themselves, “loss-events.” This work will use the consequences in terms of scenario development that, in turn, lead to loss events. For a purely hypothetical example, if water jets resulted in “induced vessel motions” that caused a crewmember to lose their balance and fall, the fall would be the loss event.

Table 1. Possible consequences for control measures.

Control Measure	Consequence	Description
<b>Electrified Barrier</b>	Activity-Related Electric Shock	Electric shock to a person on a vessel in the conduct of “normal” navigational activity over or near the electrified barrier.
	Contact-Related Electric Shock	Electric shock to a person on a vessel or the shore that occurs as a vessel comes alongside an approach wall or another vessel.
	Person in the Water (PIW)-Related Electric Shock	An electric shock to a person that is in the water near or over the barrier array.
	PIW Rescuer-Related Electric Shock	An electric shock to a would-be rescuer resulting from an attempt to remove/rescue a person from the water near or over the barrier array. The would-be rescuer could either be on a vessel or on the shore.
	Spark-Related Vapor Ignition	Ignition of flammable or explosive vapors (released from a vessel) due to the occurrence of a spark while a vessel is over or near the barrier.
	Congestion-Related Collision, Allision, or Sinking	Because of barrier one-way restrictions, vessels will “stack-up” and provide opportunities for CAS in areas nominally without congestion
<b>Complex Noise</b>	Aural Interference	Temporary increase in ambient noise level resulting from generator/vessel interaction that hampers communication among vessel crew or between vessel crew and shore crew
<b>Water Jet</b>	Induced vessel motions	Yaw, heave, pitch, roll resulting from water jet operation
<b>Lock Flushing</b>	Induced vessel motions	Yaw, heave, pitch, roll resulting from lock flushing
<b>Carbon Dioxide Injection</b>	Increased ambient CO <sub>2</sub> levels near chamber/approach	As the water in the chamber releases CO <sub>2</sub> to the atmosphere, ambient concentrations may increase to a level that affect operations



### **3.3 CSSC - BRLD Comparison**

In the course of the preliminary work to date, multiple individuals have compared the proposed BRLD electrified barrier to the multi-barrier arrays (Barrier I, Barrier IIA, and Barrier IIB) at Romeoville on the CSSC.

#### **3.3.1 CSSC**

The Romeoville barriers are in a relatively straight, north-south section of a CSSC reach with a waterfront facility (Oxbow Midwest Calcining, LLC) just upstream of the barriers on the LDB, mile marker (MM) 296.7, a pipeline arch at the southern end of the upstream facility, a highway bridge just south of the southernmost barrier (MM 296.1), and a presently inactive waterfront facility just downstream of the highway bridge on the right descending bank (RDB).

Except for activity associated with the Oxbow facility, in normal circumstances, there is no commercial need for towboats and flotillas to stop, make or break tows, moor, or lay-up alongside the canal walls. The existing, marine safety related, regulated navigation area (RNA) provisions for the CSSC are tailored to these conditions and include a provision that personnel should remain inside and, if on the open deck, wear a life jacket. Generally, these provisions intend to minimize the chance of falls into the water, either while a vessel crosses the barriers or in a location that would sweep a person in the water across the barriers. With respect to the Oxbow facility, a “fall prevention system” incorporates a travelling car on a rail above the barge-loading wharf to prevent loading personnel, cargo surveyors, or others from falling into the water.

Review of a 2011 RDC report on rescue in electrified water at the CSSC showed that free field electrical current greater than 9 milliamps (mA) (the level at which a normal person would lose muscle control) extended approximately 400 feet north of the center of Barrier IIB and south of the center of Barrier IIA. McInerney (ibid.) shows the “hazard zones” for the combination of Barriers IIA and IIB to extend approximately 425 feet north of the center of Barrier IIB and approximately 425 feet south of Barrier IIA.

The barriers have operated safely since 2009. However, anecdotal remarks by towboat crews have alluded to “fireworks” when crossing the barriers, and include an instance of a towboat’s knee pudding smoking in conjunction with sparking activity while crossing the barriers.<sup>5</sup>

#### **3.3.2 BRLD**

The BRLD electric barrier is expected to be approximately 1950 feet from the downstream Brandon Road lock gates in a proposed “engineered channel.” The engineered channel would be constructed within the currently existing approach channel, which is semi-isolated (from river flow) (MM 285.4, LDB).

Approximately 1500 feet downstream of this location on the RDB, there is a cooling-water inlet canal for the NRG Joliet Generating Station. This is almost directly across from the downstream extent of the natural river outflow from the Brandon Road Dam. Vessel operators indicate that they encounter a cross-current when transiting this area enroute to the lock approach channel.<sup>6</sup>

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<sup>5</sup> Personal discussion, author and unnamed towboat operator, GLMRIS-Brandon Road –Navigation Safety Meeting, August 8, 2016

<sup>6</sup> Comments from unnamed towboat operator, GLMRIS-Brandon Road –Navigation Safety Meeting, August 8, 2016



In general, upbound vessel traffic proceeds at a much-lower speed than in the CSSC at Romeoville. For the most part, a towboat operator is concerned with safely maneuvering the tow across the aforementioned cross-current, lining up the tow so as to avoid contact with the banks of the approach channel below the approach walls and minimizing contact normal to the approach walls, to prevent damage either to the tow or the concrete approach walls.

As of November 2016, USACE does not intend any control measures in this project above BRLD. This preliminary risk assessment will focus on those activities that may occur either in the lock chamber, downstream approach, or further downstream to MM 285.0. In August 2016, USACE raised preliminary discussion in terms of developing a new barge fleeting area from MM 283.4 to 284.1 LDB so as to avoid flotillas exceeding 550 feet in overall length.<sup>7</sup> (Though not originally in the scope of this risk assessment, we will address the concept later.) Different scenarios and risk mitigation measures may indicate that making and breaking tows in an open reach, rather than in the comparatively still waters of the BRLD approach channel actually increases risk.

#### 4 DEVELOPMENT OF RISK RELATIONSHIPS

The discussion of control measures allows relation of their geographic location to activities and participant categories as a basis for scenarios and consequence types. Over the next section, this report will informally categorize normal, day-to-day activities and events in terms of “hazard.” The report will use a color-coding convention where “reddish” fill indicates a state that might yield a more negative effect than one indicated by a “greenish” fill. Note: As stated in the introduction, this is a preliminary risk assessment. The author is solely responsible for assignment of the subjective, non-quantitative valuations. In a full, quantitative risk assessment, all assumptions and valuations would be presented to subject matter expert panels to determine actual validity and assignment of likelihood (or probability) and severity (level of hazard and consequence values, i.e. loss or damage.). For this preliminary risk assessment, even if assumptions here are incorrect or inaccurate, later quantitative assessment provides the opportunity for clarification and revision.

As an example of the “color-shading” convention, the report will categorize location. Between the location of the various elements of the control measures described above (understanding that most of the control measure layouts shown are “conceptual” and control measure effects have a significant degree of uncertainty) and the top-level consequences noted in Table 1, we assign location-based “condition” rankings in Table 2.

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<sup>7</sup> USACE Presentation - GLMRIS-Brandon Road –Navigation Safety Meeting, August 8, 2016





Table 2. Color-ranking of conditions with respect to distance from lock.

Location with respect to chamber (distance below)	Description of unique conditions
Lock chamber	Turbulence associated with flushing lock
0-200 ft	Turbulence associated with flushing lock and sound from complex noise
200-500 ft	Turbulence associated with flushing lock and sound from complex noise, increased
500-1000 ft	Sound from complex noise
1000-1500 ft	Proximity to electric hazard, possible shock or spark due tow crossing barrier
1500-2500 ft	Shock or spark hazard from electric barrier
2500-3000 ft	Possible shock or spark hazard due tow crossing barrier, turbulence from water jets
3000-4000 ft	possible cross current due generating plant intake canal
4000-5000 ft	None known

#### 4.1 Vessel-traffic and Vessel Operations near Anticipated Control-Measure Locations

In an attempt to gain cursory understanding of routine vessel operations, RDC staff made multiple site visits to BRLD, held discussions with USACE lock personnel, participated in a navigation-interests workshop, and viewed a significant quantity of downstream-approach video recording.

By far, the largest number of vessels transiting the lock are commercial towboat and barge flotillas. Two other types of marine traffic are non-commercial vessels (including USACE work barge flotillas and governmental survey craft) and recreational vessels. The recreational traffic is generally seasonal, with a distinct increase in downbound, mid- to larger-sized craft during fall months. Table 3 provides 2015 data. Recreational fishing occurs near the confluence of the approach channel and the dam spillway/outflow. If recreational fishing craft approach the area from downstream and do not lock through, there is no record of their activity. During autumn months, waterfowl hunting occurs in the Des Plaines River, downstream of the Brandon Road Dam. Small recreational craft access this area from further downstream.

Table 3. 2015 Brandon Road Lock Vessel and Lockage Data<sup>8</sup>.

<b>Vessel &amp; Lockage Data (2015)</b>	
Average Delay - Tows (Hours)	1.25
Average Processing Time (Hours)	0.89
Barges Empty	4,147
Barges Loaded	7,040
Commercial Vessels	3,273
Commercial Flotillas	3,025
Commercial Lockages/Cuts	3,177
Non-Vessel Lockages	-
Non-Commercial Vessels	11
Non-Commercial Flotillas	10
Non-Commercial Lockages/Cuts	10
Percent Vessels Delayed (%)	51
Recreational Vessels	536
Recreational Lockages	305
Total Vessels	3,820
Total Lockages/Cuts	3,492

## 4.2 Commercial Vessel Activity

The commercial towboat and barge flotilla types and activity surrounding passage and lockage varies. Because tow flotillas differ in size, and the lock dimensions are 600' x 110', larger tows or long tows must reconfigure for lockage.

### 4.2.1 Person-in-the-water Scenarios

In terms of the CSSC electric barrier risk assessment, the greatest potential loss values involved person-in-the-water (PIW) electric shock and PIW rescuer electric shock. Multiple aspects of the CSSC RNA prescribe measures that reduce the probability of PIW occurrence. As stated earlier, in a “transit only” situation, many of the indicated measures will not interfere with safe vessel operation. However, in the BRLD area, tows require substantial on-deck activity for safe navigation. In many cases, to make a safe line-up on the upbound approach, including “calling distances” to the navigation channel shore or the approach walls, captains will station one to three deckhands at corners of the flotilla. Additionally, should the flotilla require multiple lockages (cuts), deckhands will occasionally help the lock crew connect the approach wall warping wires (haul wires) to the barge mooring fixtures. For the most part, the vessel crew does not cross to the lock wall, except on some of the multiple-cut lockages.

<sup>8</sup>“ Brandon Road Lock & Dam.” *Illinois Waterway, Fact Sheets-Locks and Dams*. USACE Rock Island District, Update May 2016. [http://www.mvr.usace.army.mil/Portals/48/docs/CC/FactSheets/IL/BrandonRoadLockandDam\(2016\).pdf](http://www.mvr.usace.army.mil/Portals/48/docs/CC/FactSheets/IL/BrandonRoadLockandDam(2016).pdf). 7 November 2016.



As a matter of developing comparative relationships for the different types of commercial vessel, on-deck activity, Figure 11 identifies multiple situations and applies “condition color-rankings” as done with the distances for the lock in Table 2.

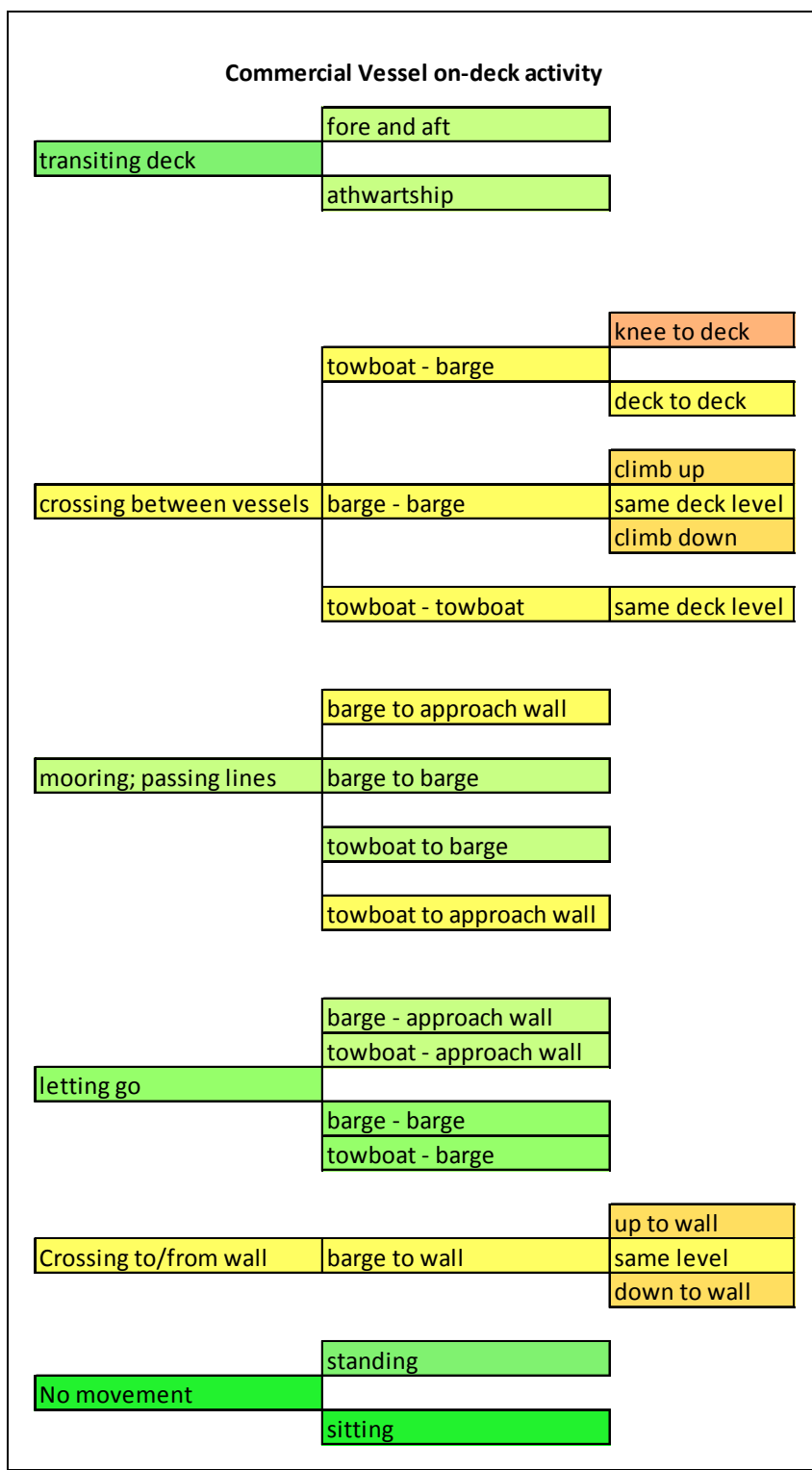


Figure 11. Comparative activity condition, commercial vessel, on-deck activity.



We will also include additional qualifiers as to where on the tow the activity takes place and weather condition in Table 4 and Table 5.

Table 4. On-deck activity location.

On-deck activity location	
Fore-aft	Athwartship
head barge bow-rake	outside barge deck coaming
head barge midships	between barge deck coaming
head barge stern	inboard (tank barge, deck barge)
middle barge bow-rake	
middle barge midships	
middle barge stern	
stern barge bow-rake	
stern barge midships	
stern barge stern	
towboat bow	
towboat midships	
towboat stern	

Table 5. Weather conditions.

Weather		
	hot	dry
calm	warm	lt rain
med wind	cool	hvy rain
hi wind	cold	freeze rain
	frigid	lt snow
		hvy snow

The four preceding tables indicate that depending on multiple, linked, conditional relationships, relatively-inconsequential, routine activity can enhance opportunities for loss, in and among themselves, specifically a PIW situation. With this in mind, we note there have been no PIW incident reports to the CG in the past ten years in the vicinity of BRLD.<sup>9</sup> (For this document's purposes, the "vicinity" refers to the lock chamber and 5000 feet downstream as in Table 2.) Whether invasive species control measures could increase the number of PIW incidents requires further investigation.

<sup>9</sup> CGBI-MISLE cube review, 22 November 2016, Sector Lake Michigan PIW cases since 2006. MST2 N. Scott & MST3 D. Caikowski, MSU Chicago. Closest PIW case: Pleasure craft trapped in Dresden Island Dam gate.



As an example, Figure 12 is an event tree that includes flock flushing and an electric barrier. The event tree considers a scenario that involves turbulence from a lock flush. For our purposes, we already know that when a flotilla requires a cut, the downstream barges and/or boat are subject to the turbulence associated with draining the lock chamber, but for an example, we need to consider this in terms of possible effect if an electric barrier is in use. Also, with the lock-flushing scheme as Figure 9 depicts, a significant number of tows that do not now lay up to an approach wall may be required to while waiting for the lock flush.

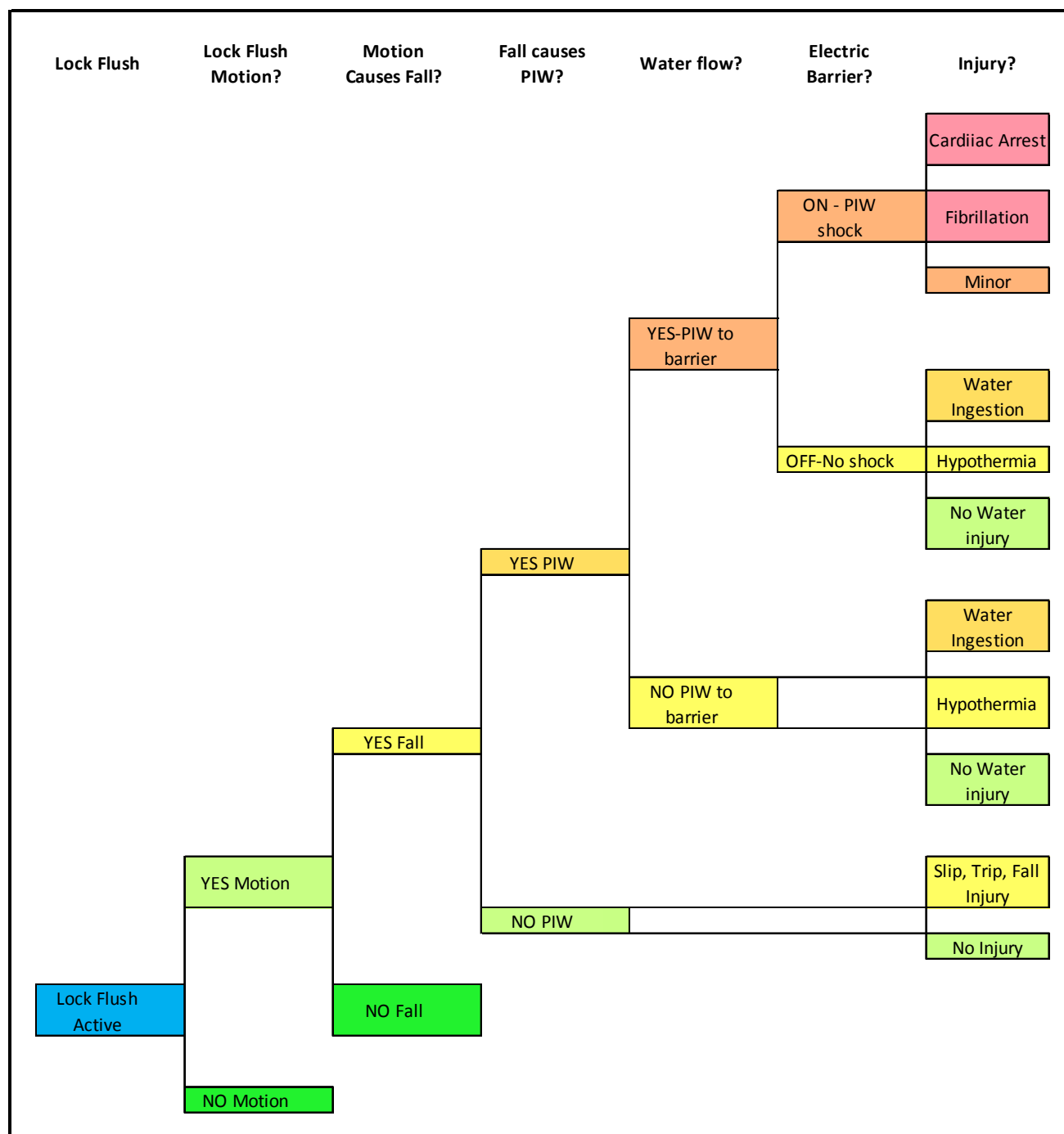


Figure 12. Example event tree for lock flushing and electric barrier scenario.



We next consider a different PIW scenario. Figure 13 shows a deckhand at the rake of an empty barge calling distances as it nears the approach wall. In this instance, the tow proceeded directly into the lock chamber. Under a potential lock-flush scenario, the tow might or might not moor, or otherwise keep station, while awaiting the lock flush. (As noted earlier, as of this writing, there is no specific procedure for vessel operations with respect to the lock flush.)

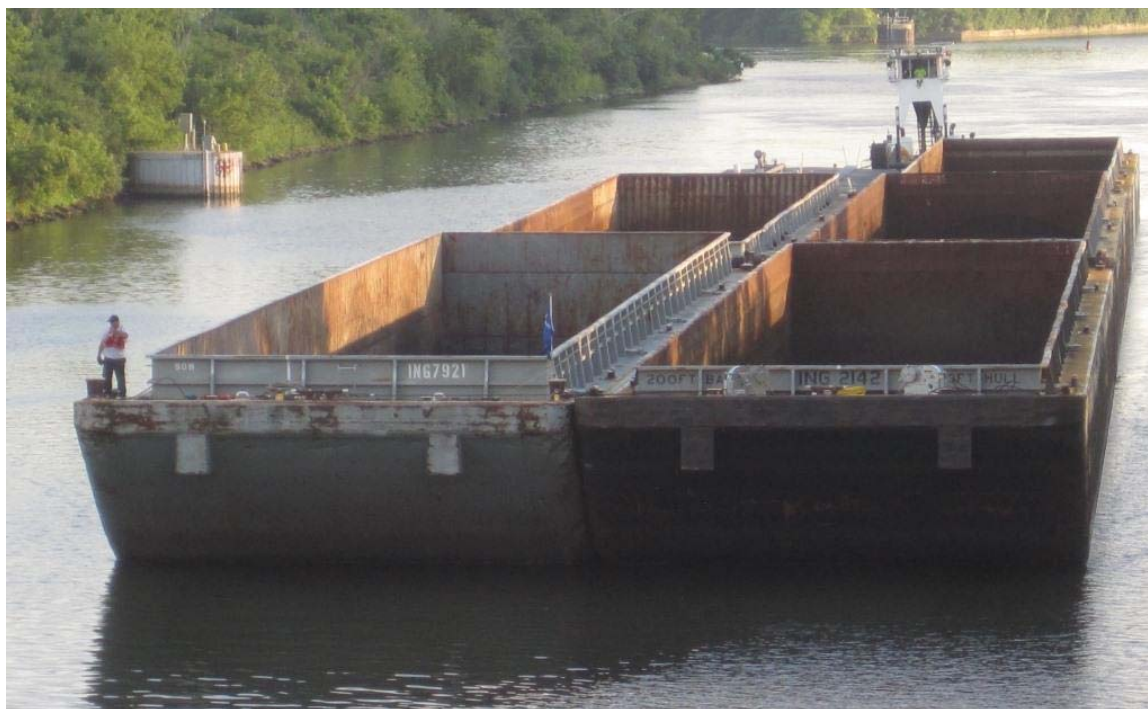


Figure 13. Deckhand at rake of light barge.

To reiterate, there have been no PIW incident reports to the Coast Guard in the past ten years in the vicinity of BRLD, but the individual or combined control measures could have an effect on what are today, inconsequential, normal, day-to-day activities. Figure 14 represents a second, PIW-related event tree not including risk from electric shock. Even without the risk from the electric barrier, consequence can be severe.



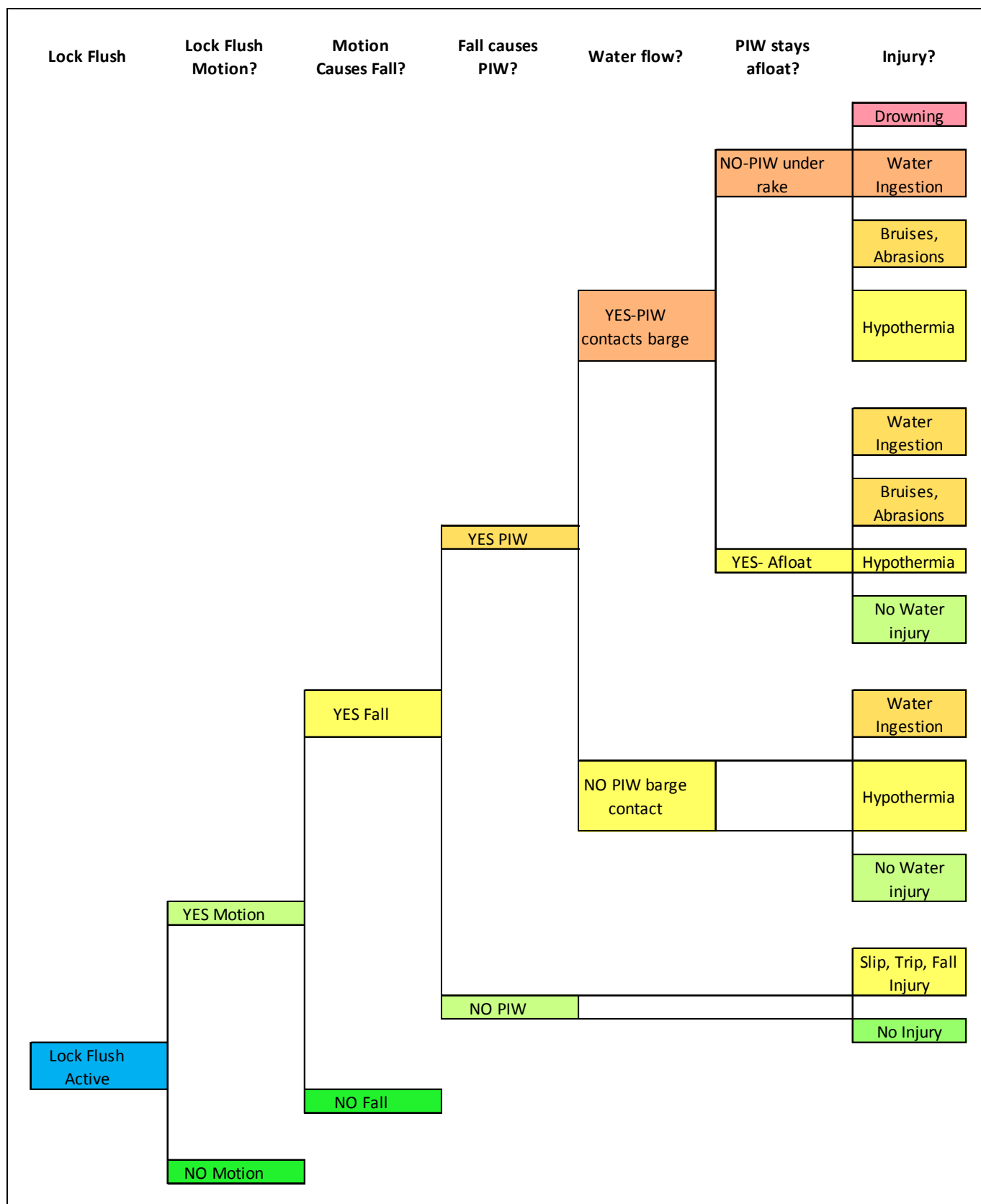


Figure 14. Example event tree for lock flushing.



The preceding examples and event trees show two examples of PIW risk. A full, quantitative risk assessment would include additional scenario event trees associated with other control measures, not only as they relate to PIW occurrence, but also as they relate to other consequence types. For example, might complex noise induce a communication error that results in a barge rake impacting either a lock gate or approach wall, resulting in damage to either the barge or the structure? Though this chain of events might not be probable, before we can rule them out, modeling and real world testing of control-measure induced conditions could reduce uncertainty.

This preliminary assessment is not able to develop each possible scenario, particularly as all scenarios include a number of unknowns. To highlight the complex scope of a full risk assessment, this work will include two electric-barrier related, commercial vessel conditions for consideration.

### 4.2.2 Electric Barrier Related Sparking and Contact Shock

Regarding an electric barrier in the Brandon Road Lock approach channel, a second commercial-vessel only condition presents another area of concern, again with a large degree of uncertainty. From the USACE 2011 CSSC in-water testing, McInerney (ibid.) discusses sparking between barges in a flotilla crossing the CSSC electric barriers and barges moored to a loading/fleeting area just downstream. The 2011 testing indicated sparking could occur with one barrier array operating, when a tow configuration was crossing the array and made contact with a steel barge, approximately 600 feet away from the barrier. Based on this, the Coast Guard operational commander included a provision in the RNA guidance that “red flag” barge transits require a “bow-boat” to both help keep a moving tow off barges moored at the fleeting wall, and to provide an additional 100+ feet separation from a potential spark and any source of flammable vapors on the red-flag barge.

As with the CSSC, there is a facility at MM 285.2 LDB where barges occasionally moor. Though presently inactive, moored barges might extend to within 1100 feet of the electric barrier. This could pose the same contact-sparking possibility as described above, but will require additional research.

As part of the control measures plan for BRLD, USACE diagrams (Figure 5 and Figure 7) indicate an “engineered channel” from the lower lock gate extending approximately 2250’ downstream. With either an engineered channel or the existing limestone formation, there is no information as to whether a tow crossing the electric barrier would induce sparking if the tow contacted the engineered channel walls or the existing limestone. With this in mind, we should consider precisely where tows might contact the new approach wall. We’ll assume two things, (1) the dimensions close-in to the lock will remain the same, with the channel wall (LDB) narrowing to 110 feet approximately 350 feet downstream of the chamber, and (2) when tows lay up for lock drain (as per Figure 9, just downstream of the lower gates), they will be on the RDB. Figure 15 shows a section of the RDB approach wall extending approximately 650 feet downstream from the chamber. Four steel “rub rails” imbedded in the concrete structure allow barge contact (impact) without damage to the concrete. (Figure 16 shows a close-up of the rub rails on the LDB.) Depending on the downstream extent of this steel rub rail, the barrier might induce a spark-related event, should a long-tow contact the steel rub-rails while a portion of the tow is over the electric barrier.





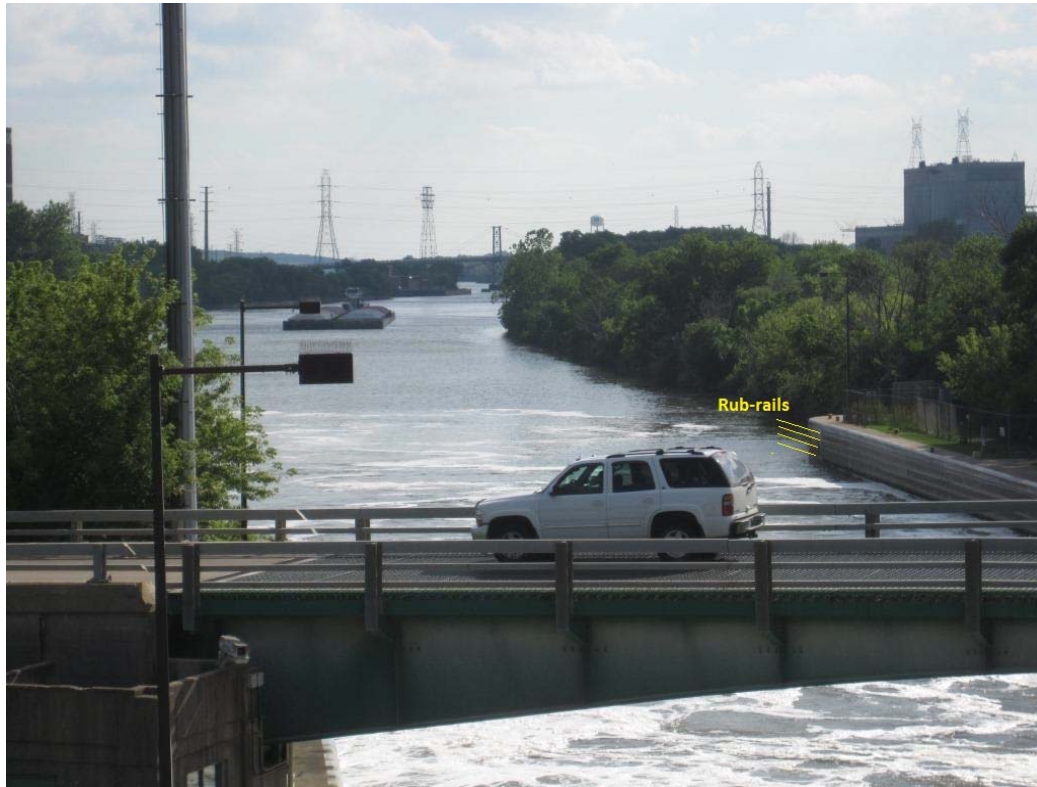


Figure 15. Location of rub-rails on LDB lower approach wall.



Figure 16. Close-up of rub-rails on LDB approach wall.



An additional electric-barrier related concern includes activity-related and contact-related electric shock. The present, conventional, commercial navigation practice of one-way traffic through the area, beginning at approximately MM 285.2 (Joliet Generating Station), precludes, for the most part, barge-to-barge contact between different flotillas anywhere near the proposed barrier location. However, from the 2011 CSSC testing, McInerney (ibid.) indicated that use of wire rope kept voltage potentials between barges within a flotilla to a minimum, and referenced 2005 testing that indicated “soft-line connection values of about 250 volts previously measured for Barrier I.” The 2011 testing did indicate that voltage differences between “outside barges” and towboats ranged from approximately 3 volts to 36 volts. As McInerney states, “higher voltages measured between barge and tugboats are the result of a higher resistive path between the tow and barge, due to the rubber bumpers and cable-to-winch connections.”

Although RNA provisions require that “commercial tows transiting the RNA must be made up with only wire rope to ensure electrical connectivity between all segments of the tow,” the earlier reference to “fireworks” when transiting the CSSC barrier may indicate a need for reevaluating optimal electrical conductivity between towboat and barge.

### 4.2.3 Electric Barrier Related, Congestion-Based Collision, Allision and Sinking

In the CSSC risk assessment, the analysis team brought to light concern that the one-way transit in the RNA, based on the rule that vessels “may not pass (meet or overtake) in the RNA”, could result in congestion above or below the RNA that might increase the chances for collision, allision, or sinking. As noted above, present, conventional, navigation practice dictates one-way traffic downstream to MM 285. Presently, flotilla lockage delays cause congestion, both upstream and down. Since the new project does not include enlarging the chamber, lockage delays (as noted in Table 3) will drive congestion.

### 4.2.4 Transferring Risk from the Electric Barrier Location

Earlier, the report mentioned preliminary USACE discussion in terms of developing a new barge fleeting area from MM 283.4 to 284.1 LDB so as to avoid flotillas exceeding 550 feet in overall length. When viewed in terms of congestion, this move would exacerbate delays and increase the number of transits across the proposed electric barrier. This concept of a new fleeting area also potentially increases the opportunity for a PIW situation, due to breaking and making of tows in a flowing stretch of the Des Plaines River (rather than in the relatively still waters of the approach channel). A limited incident report review showed that in 2015, of the 6 towing vessel or barge crew fatalities nationwide, one crewmember fell from a barge in a fleeting area<sup>10</sup> and two other fatalities involved towboats capsizing during fleeting operations.<sup>11, 12</sup> Further consideration of this strategy requires its own quantitative risk assessment.

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<sup>10</sup> U.S. Coast Guard-American Waterways Operators Annual Safety Report, National Quality Steering Committee Meeting, August 3, 2016.

<sup>11</sup> <https://www.workboat.com/news/coastal-inland-waterways/ntsb-downstreaming-high-water-factors-in-fatal-la-capsize/>

<sup>12</sup> <http://www.professionalmariner.com/December-January-2016/Mariner-killed-when-towboat-goes-out-of-control-sinks-in-swift-current/>





### 4.3 Non-commercial Vessel Activity

The 2015 data in Table 3 indicate that all but one non-commercial lockage involved a “flotilla.” The author will assume this indicates USACE vessel activity (Figure 17). Further, this activity can be more-closely associated with commercial flotilla transits, both in size and activity (except where the USACE flotilla conducts maintenance activity within the BRLD vicinity). Table 3 does not, however, indicate whether any governmental survey or fish collection activity occurs in the downstream area, or whether any type of “patrol activity” occurred. This absence of information can only be reconstructed from other-agency activity records, or through future monitoring.



Figure 17. USACE M/V Channahon with two barges.

### 4.4 Recreational Vessel Activity

From observation and review of video recording, a significant percentage of recreational boats that lock through are greater than 30 ft length over all (LOA) (Figure 18). A cursory review of lockage data during August 2016 indicated that approximately 80 percent of all recreational vessel lockages involved downbound transits, and 60 percent of recreational vessel lockages were single vessel, but on occasion, recreational vessel flotillas involved as many as 5 boats. From this high percentage of downbound transits, we will assume that many of the large vessels in the later months are considered “Loopers” making the transit from the Great Lakes to the Gulf of Mexico. As “Loopers”, they will have already transited the CSSC electric barriers.

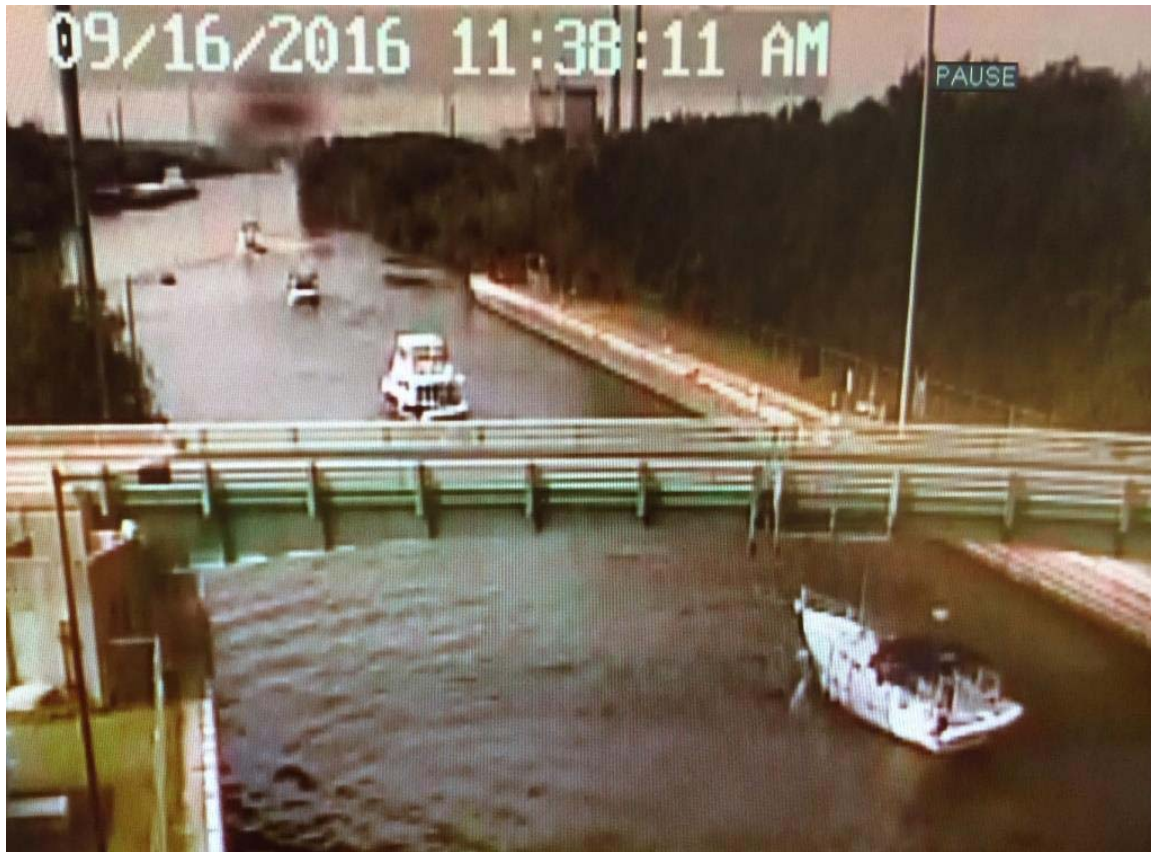


Figure 18. Downbound recreational vessel flotilla – 4 vessels greater than 30' LOA.

For recreational vessels, electric barrier transit could include the same regulatory precautions as the CSSC RNA, but the lock flush, complex noise, and CO<sub>2</sub> application all require modeling and experimentation applied to recreational vessels to determine what measures will be necessary for minimizing the possibility of adverse impact. As an example, records show the occasional recreational vessel locking through with a commercial barge flotilla. If a recreational vessel is waiting for the same lockage and the vessel is well into the approach channel, it could be subject to the same turbulence as the barge flotilla, but might react with a violent, rather than a relatively benign, motion. Recreational vessel lockage activity regulations and procedures will require updating to address the specific control measures.

Smaller recreational vessels often enter the area at the confluence of the approach channel and the Des Plaines River Brandon Road Dam spillway, but these events are not documented. On multiple occasions, review of the video recording shows vessels that appear to be fishing. Also, lock operators indicate that during fall months, small vessels regularly approach the area from downstream, then navigate toward the spillway area for waterfowl hunting (Figure 19 and Figure 20).

The photo and satellite image do not fully indicate the water shallowness around the blinds, but the number of visible shoals give some indication. To navigate these shoal areas, sportsmen must either use a small (less than 20' LOA), shallow draft boat, or access the blinds from the USACE controlled area between the lock and the spillway.







Figure 19. Location of waterfowl hunting blinds in Des Plaines River.



Figure 20. Waterfowl hunting blind near Brandon Road Dam spillway.

One uncertainty associated with the electric barrier is the degree the electric field might extend past the engineered channel, and the degree the field might extend into the spillway area. Though actual measurements would indicate the exact nature of field spread, barrier operation might induce a hazard-zone, and impact the preexisting, already regulated, waterway activities (hunting and fishing). Early on, lead



agencies must include the potentially affected user groups and specific regulatory agencies (e.g., Illinois Department of Natural Resources) in planning and discussion.

In an indirect attempt to determine the present state for first response water-rescue capability in the area downstream of BRLD, the author did not identify any existing resources. Though a search of the Coast Guard Business Intelligence showed no incidents reported in the Marine Information for Safety and Law Enforcement data base in the BRLD vicinity, this does not necessarily indicate that incidents did not actually occur requiring a first response capability.

### 4.5 Non-vessel Activities near Control Measures

At present, USACE lock personnel control lock fill and drain, gate operations, and barge shuttle for all lockages. With the proposed electric barrier, the physical extent of the overall project could include operating personnel 2000 feet, or so, from the lock control house. As USACE has its own occupational health and safety program, this report will not examine, review or add to their internal procedures for those individuals under USACE control, including contractors and authorized visitors.

Figure 21 shows the areas associated with BRLD that USACE controls. Though fencing, gates, and surveillance limits access to the working areas East of Brandon Road, on a November 2015 walk in the vicinity of the LDB approach area, the author saw signs of trespass, including litter.

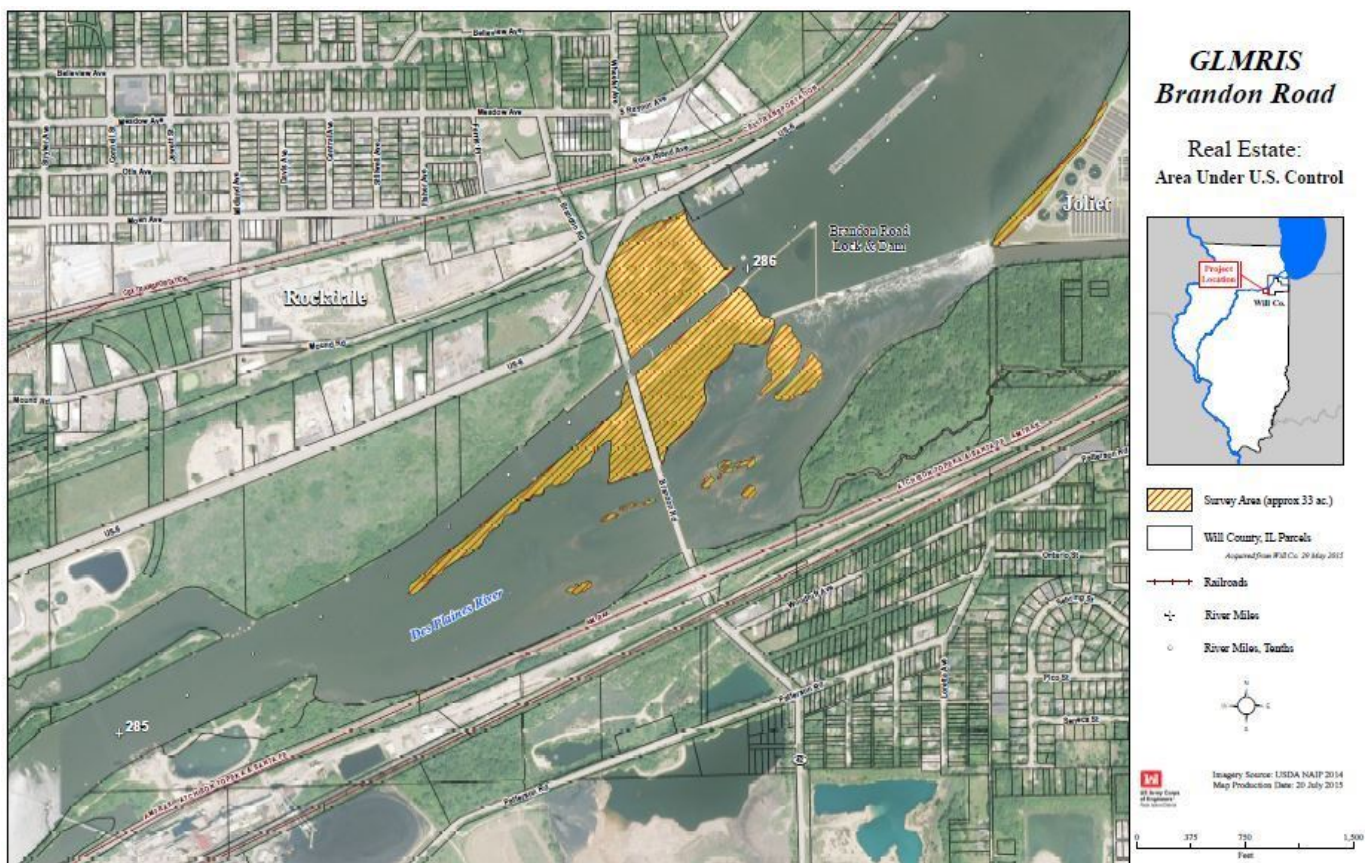


Figure 21. Brandon Road real estate under US control (USACE).





A review of Will County, Illinois land records indicates Midwest Generation, LLC of Princeton, NJ owns the three parcels adjacent to the downstream RDB approach. Examination of satellite imagery indicates an access path from Brandon Road to the approach channel shore, downstream of the existing RDB approach wall. The significance here is that agencies will need to limit access to the approach channel (or engineered channel), particularly to prevent persons from land to enter the water in the vicinity of an electric barrier.

## **5 MARINE-SAFETY RISK MITIGATION STRATEGIES**

The above discussion indicates multiple opportunities for “intervention” measures to either limit the likelihood of an event, or to interrupt the progress of an event tree scenario towards a negative consequence (loss). At a minimum, planning, staffing, and operational procedures can mitigate the degree of loss.

For planning, development, and implementation of the control measures, while minimizing their effect on waterborne commerce, recreational activity, and marine and navigation safety, the multi-year time frame before actual control-measures implementation provides the opportunity to investigate “intervention” measures more thoroughly.

### **5.1 Project Design, Construction, and Operation**

The following are broad categories of conditions that can reduce risk exposure. Though many of these items fall within USACE purview, Coast Guard awareness and participation in their implementation will expedite final operational plan approval.

Limiting access to areas upstream of an electric barrier and the in-water hazard zone on non-USACE controlled property (RDB) and USACE controlled property (LDB) with fencing and gates, with suitable access points for shore-based rescuers on both sides of approach channel.

Continuous monitoring and surveillance (video system) to easily detect and observe all activity in the vicinity of the electric barrier hazard zone, including both authorized and unauthorized individuals, persons-in-the water, and vessels that encounter problems.

Staffing for control-measure operators, to include barrier operation monitoring, safety oversight, and control measure intervention, i.e. electric barrier shutdown, automated/remote lock flush and lock drain quick closure, complex noise reduction, etc. Figure 22 and below, (adapted from Figure 12) gives an example of how “control-measure intervention” can interrupt or change a scenario event-tree outcome.

Siting for storage and launch of a fast response boat (non-conductive hull) for use in the lower pool level.

Installing and outfitting basic, shore-based water-rescue stations for the full length of the engineered channel on both sides, to include non-conductive rescue equipment.

Developing an emergency response plan that includes local jurisdictions.



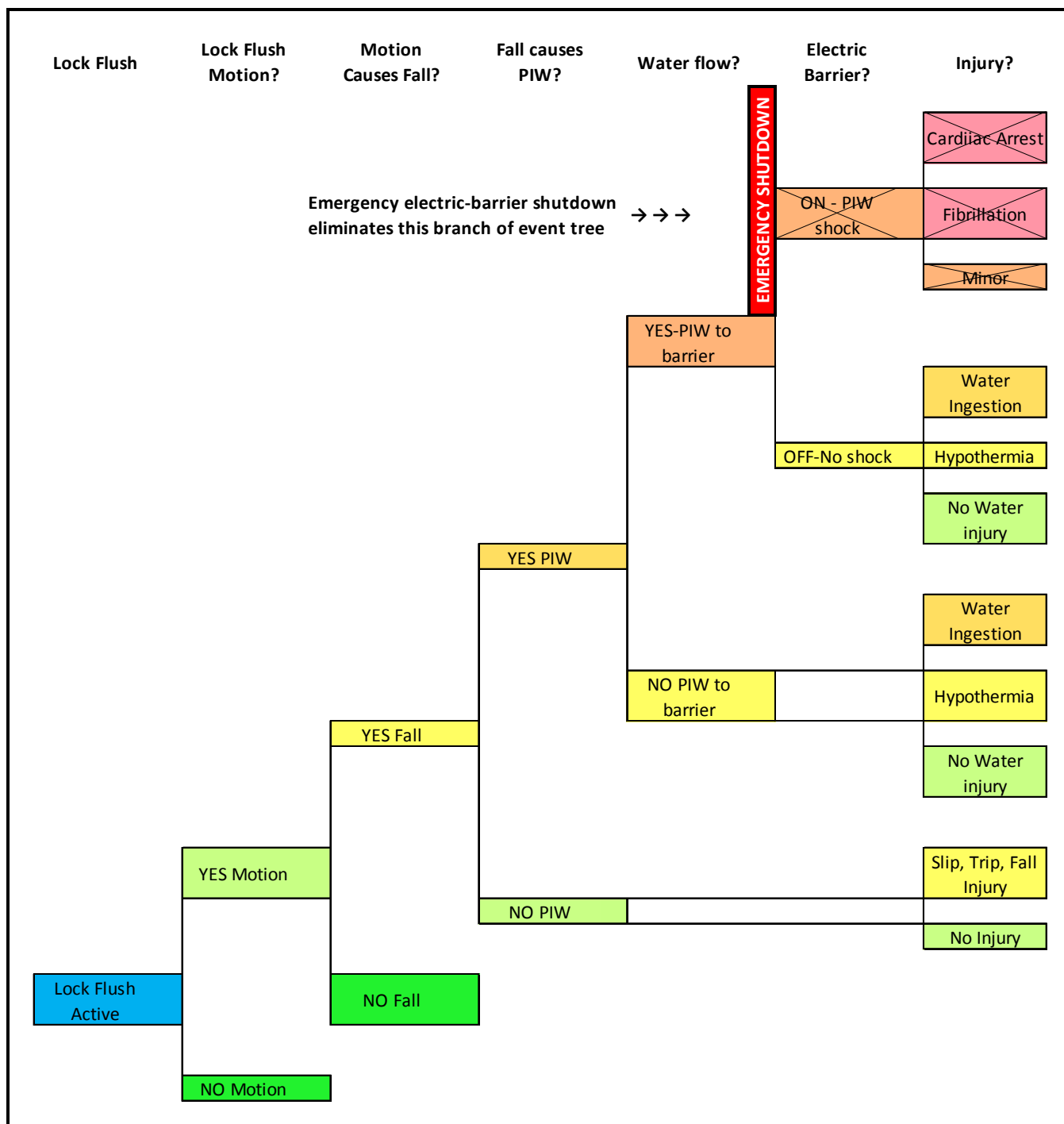


Figure 22. Example of control-measure operation intervention effect on scenario event tree.



## 5.2 Safety Testing and Analysis

Electric barrier testing along the lines of the USACE and RDC CSSC testing to determine:

- In the water and along the shore hazard zones, including areas that would allow a rescuer to safely extract an individual from the water,
- Whether sparking-to-shore will occur with longer tows, if one end of the tow is over the barrier and the other contacts the shore or any conductive structural elements of either approach-wall section of the engineered channel, or barges moored downstream on the LDB,
- And if existing wire-rope barge-to-barge and barge-to-towboat mooring configuration is adequate to prevent sparking within a flotilla.

Lock flushing and barge entrainment (water jet) testing to determine the level of motion the different control measures impart to loaded and empty barges, and to smaller vessels in the 20-40' range.

Complex noise testing to determine the optimal level of sound generation consistent with safe vessel operation.

CO2 application testing to determine levels of concentration, above ambient, that may have an effect on vessels or their operators.

## 5.3 Vessel Operations, Geographic and Behavioral Restrictions

Identifying and highlighting adverse-event (risk-negative) operational procedures and scenarios that may have straightforward, best-practice resolution.

Reviewing CSSC operational guidance (RNA and Safety Zone regulations) with industry and recreational boater focus groups to develop, analyze, and recommend specific measures regarding operational risk scenarios applicable to future navigation rules. Figure 23 gives a clear example of possible application of a particular CSSC rule to crossing the proposed barrier: an individual on a recreational vessel, apparently not wearing a life jacket, standing at deck edge after clearing lock.

Determining the need for first response water rescue capability trained in safe, PIW and small-vessel rescue, in conjunction with control-measure interventions.



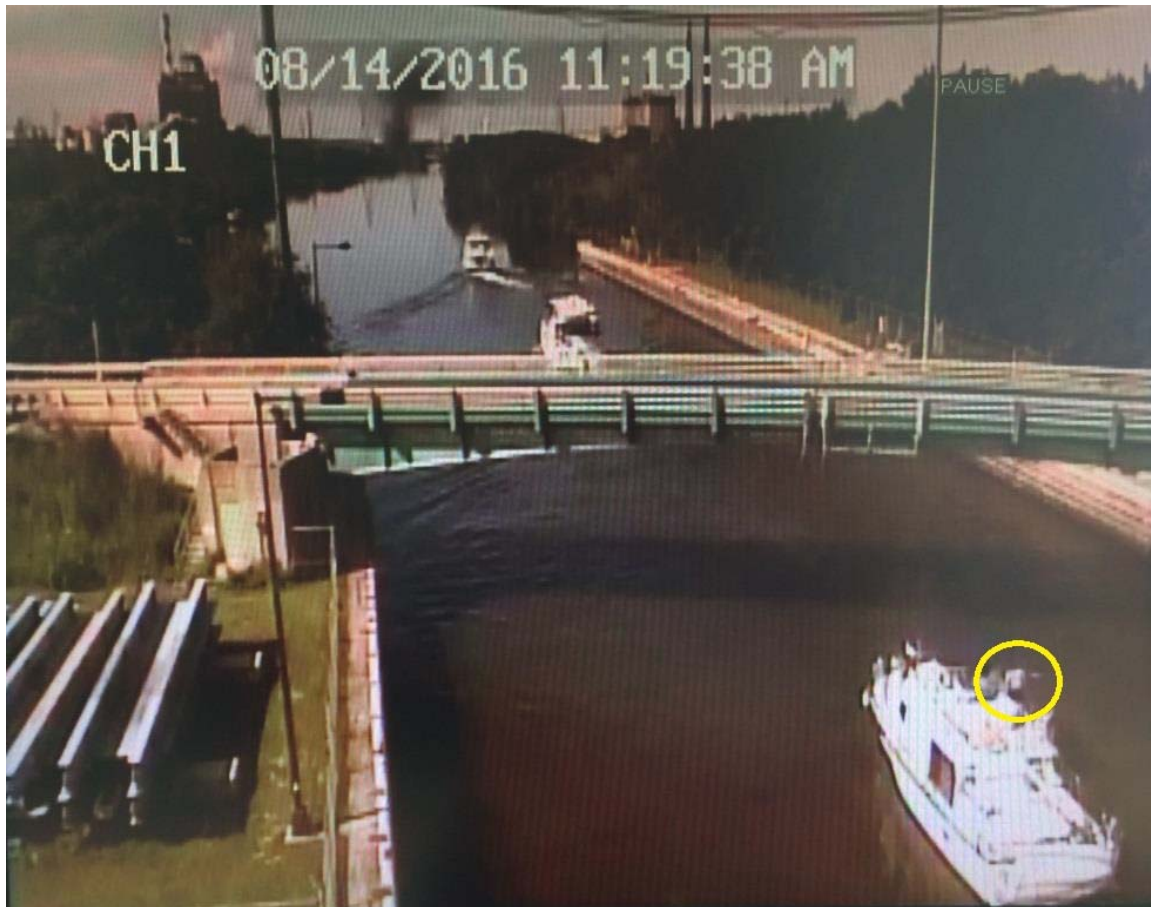


Figure 23. Recreational vessel (yellow circle highlights individual standing at deck-edge without life jacket).

## 6 CONCLUSIONS

Of the different, potential invasive species control measures, and fully acknowledging the 10 years of safe operation of the CSSC electric barrier system, the proposed electric barrier most likely contributes the greatest amount of risk to marine safety, specifically with respect to PIW-related electric shock (including PIW-rescuer electric shock). The electric barrier would probably also contribute to vessel operations risk categories (commercial or recreational vessel activity related electric shock and sparking). The other potential control measures, including flushing lock, complex noise, fish-entrainment water jets, and carbon dioxide application may all contribute additional elements of risk to the entire control measure system, but at this stage of development (experimental modeling and conceptual operating plans), we are not able to reasonably determine the degree of relative contribution to the overall risk.

Despite the significant degree of uncertainty associated with individual elements of the control-measure system, we are confident that through both technical and operational engagement with USACE and navigation interests, including input to the specific goals of individual control measure modeling and testing, the Coast Guard can be well-prepared to evaluate, in a timely manner, phased or concurrent control-measure implementation in terms of navigation and marine safety.



Test and model efforts regarding invasive species control measures require Coast Guard input for test-plan elements directly related to marine and navigation safety. As an example, if hydrodynamic modeling includes the effect of lock flushing on a barge flotilla, the Coast Guard might require determination of expected motions on flotillas or barges of different configuration, and on recreational vessels that might be subject to a lock flush (or other equivalent testing).

Throughout the design, construction, and implementation process, Coast Guard input to USACE on specific control-measure monitoring and emergency intervention measures and procedures (e.g., electrical hazard zone monitoring and surveillance and emergency shutdown) could expedite later review and concurrence with proposed operating plans.

As the project moves along, working hand-in-hand with navigation interests, including sharing test information and developing best-practices, will enhance progress for developing and implementing new, goal-based safety regulations.

## **7 RECOMMENDATIONS**

The Research and Development Center should continue Illinois Waterways risk research efforts, particularly in a technical advisory role to the Coast Guard operational commanders. Incremental progress in control-measure planning, design and construction requires close attention to navigation safety and risk mitigation.

Coast Guard operational commanders should evaluate the information presented here in terms of the Tentatively Selected Plan review. As noted in the conclusions, through technical and operational engagement with USACE and navigation interests, the Coast Guard can evaluate in a timely manner, control-measure implementation in terms of navigation and marine safety.

Operational commanders must engage USACE so as to include waterway-safety risk awareness and consideration throughout the development and fielding of the individual control measures. The Coast Guard should plan for additional risk assessments as USACE fields the individual control-measure technologies. Operational testing and safety testing of each control measure provides the opportunity for additional evaluation.

Since the combination of control measures might reflect a complex environment, operational commanders should consider a formal risk assessment that accounts for all control measures, once the measures are ready for service.



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